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A MULTIPLICITY JUMP TRIGGER FOR FIXED TARGET CHARM AND BEAUTY EXPERIMENTS

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ABSTRACT

Using the E791 spectrometer we have tested a multiplicity jump trigger that makes use of thin quartz plates to count the number of particles before and after a decay region just downstream of a thin tungsten target struck by a 500 GeV pion beam. The detector is sensitive to about 2.7 tracks being created between the plates at the 1 sigma level. This performance level may enhance charm events by a small amount, and should lead to an enrichment of well over 100 for $B\overline{B}$ events.

1. INTRODUCTION

As many $B\overline{B}$ events are produced in each spill during Fermilab fixed target running as have ever been produced at CESR. The difficulty that has yet to be overcome is to separate the very rare $B\overline{B}$ events from the ordinary hadronic interactions in a high luminosity experiment.

$B\overline{B}$ events are expected in roughly $3\text{x}10^{-7}$ of the interactions, making them about three orders of magnitude less abundant than charm events[1]. A multiplicity jump trigger offers a fast and simple way of identifying the presence of secondary vertices from the B meson decays. In addition, a trigger of this type offers more than a hardware track finder since it adds information of it's own about the presence of secondary vertices. It can therefore improve the final signal to background ratio even if it is not used as a trigger.

Many attempts have been made in the past to create a multiplicity jump trigger. Tests using two scintillators[2] failed due to large Landau fluctuations of the relativistic particles and large signals from the nuclear fragments of the heavy target. Several tests[3,4,5] with silicon microstrip detectors (SMD's) and silicon wafers have looked encouraging, but those that have been installed in running experiments[6] failed due to problems with online calibration, electronic noise, and stability of the electronic gains. This test explores a new method using Cherenkov radiation from two quartz radiators instead of scintillators or silicon detectors.

Non-relatavistic nuclear fragments and delta rays make no Cherenkov light, and there are no saturation effects as in scintillators and silicon detectors. The difficulty with this approach is that there is only a small amount of Cherenkov light generated per track. The technical question addressed by this test is whether the small amount of light is sufficient to make a precision measurement of the number of particles in each plate, and if other unexpected factors contribute to the resolution.

2. THE DETECTOR

The detector used in this test consisted of two 1/2" x 1/2" x 2 mm UV grade quartz plates separated by about 2.5 cm as is shown in Figure 1. A thin tungsten target was mounted about 1 cm upstream of the first quartz plate providing a gap between the quartz and the target detectable by the offline reconstruction of the SMD information. This gap allowed the separation of interactions in the target from those in the first quartz plate. A multiplicity jump trigger, if used in a future experiment, will have a third thinner quartz plate just downstream of the target that is used to determine that the interaction originates within the target.

Each quartz plate was viewed on two sides by a UV sensitive Hamamatsu R2027 10-stage linear focused phototube. The quartz plates rested on a steel bar, and were optically coupled to the phototubes with GE Silicones VISC-600M silicon coupling grease. The plates were aligned to a precision of about $1/2^o$ using a small laser.

Quartz has an index of refraction of 1.45-1.57 in the visible to UV range, and the Cherenkov angle for relativistic particles is about 47.9^o. The angle of total internal reflection is about 42.1^o, so all the generated light is reflected to the edge of the counter. Cherenkov radiation is detected for all tracks with an angular divergence less than 100 mrad, which is adequate for most B decay tracks. Slower nuclear fragments and delta rays will either make a little less light if they are relativistic, or much less light if the Cherenkov angle is smaller than the angle of total reflection.

For relativistic particles roughly 110 photons are produced per track in the range of 180-450 nm. The light collection efficiency across the face of the quartz plate is very uniform and averages about 65%. The R2027 phototube has a quantum efficiency that averages about 15% over the range of 180-450 nm. Combining all these factors yields a net estimated yield of about 5-7 photoelectrons per β=1 track in each phototube.

The data in this report were taken on the last day of the Fermilab 91-92 fixed target run with the apparatus mounted in the standard target position in front of the E791 spectrometer, described in detail elsewhere[7]. Useful to this analysis are the 17 downstream SMD planes with pitches of 25μm and 50μm, and the large drift chamber system downstream of two large dipole magnets used for momentum analysis. The pulse heights from the four phototubes were digitized with a LeCroy 4300B FERA ADC system and included in the normal E791 event records.

Data were taken with 500 GeV/c pion beam under a number of operating conditions with two types of triggers. One trigger simply selected non-interacting beam, the other triger used one of the four phototube signals to select interactions.

3. TEST RESULTS WITH BEAM TRIGGERS

Several test runs were taken at low beam intensity by triggering on every beam particle. We selected events with a single reconstructed beam track, single minimum ionizing pulse height in the beam trigger counter, total energy deposited in the calorimeter between 300 and 550 GeV, and an x-y position of the beam track within a 6 mm diameter fiducial region centered on the plates. The z-axis is defined to point along the beam direction. Figure 2 shows single minimum ionizing signals from one of the phototubes after a factor of 10 amplification with a LeCroy 612A photomultiplier amplifier. The extremely small noise level was obtained by careful attention to detail to eliminate pickup of ground loop noise. The RMS width of the signals is consistent with 5 photoelectrons detected per track, in good agreement with the estimated yield.

Interactions were defined as events meeting the above requirements with an additional requirement that the sum of the transverse energy in the hadronic calorimeter, E_t, be greater than 4 GeV. To avoid confusion from large noise signals we required the pulse height from the two phototubes on each plate to agree within 3 minimum ionizing particles (MIPS). These cuts simply define a clean sample of almost unbiased interactions. Figure 3 shows the reconstructed z position of the primary vertex for these events. The target, the two quartz plates, and the thin windows of black plastic tape are clearly visible. To avoid confusion from primary interactions within the quartz plates we only accepted events with a primary vertex in the range z=-16 cm to z=-15 cm.

To check that the quartz plates actually counted the number of charged tracks we compared the pulse height in each plate with the number of tracks reconstructed using the SMD and drift chamber system. Figures 4 and 5 show scatter plots of the correlation for the upstream and downstream quartz plates. There is excellent correlation between the two measurements of the number of tracks, but the quartz plates appear to detect a small additional component. This may indicate that target fragments from the tungsten target are being detected by the quartz plates, and could be caused by the quartz plates scintillating at a very small level or by the phototubes directly picking up the nuclear fragments as in a microchannel plate. The difference between the intercepts in Figures 4 and 5 causes a small offset in the measured multiplicity jump as described below.

The correlation of the upsteam and downstream pulse heights in non-biased interactions is a useful measure the usefulness of this device as a trigger. In Figure 6 we show the measured number of particles appearing in the decay region between the plates for interactions of multiplicity 6-20. Events with secondary vertices from heavy quark decays produce a positive signal in Figure 6. There is a slight loss of particles in the decay region that is about the same size as the difference in the intercepts in Figures 4 and 5. The RMS width of the signal is 2.7 MIPS and has a gaussian shape with no visible tails. Strange or charmed particles decaying between the plates would be visible in Figure 6 if they occured at a significant rate. Interactions of the secondary particles in the quartz plates should produce a small tail on the right hand side of the peak in Figure 6, but the resolution is not sufficient to resolve this effect.

Figure 7 shows the measured resolution as a function of multiplicity. If the resolution were dominated by photon counting statistics we would expect it to increase as the square root of the interaction multiplicity. The curve is the extrapolation of the single particle resolution to higher multiplicities. It appears that the resolution is slightly worse than expected from photon counting statistics alone.

4. MEASUREMENT OF MULTIPLICITY JUMP FROM K^0_s DECAYS

To collect a large sample of interaction events we used signals from one of the two phototubes on the upstream quartz plate in the E791 "interaction trigger". The signals from this phototube had to pass through a 75 ohm hardline with 50-75 ohm matching pads at several locations in order to arrive in time to make the trigger decision, which injected ground loop noise. This phototube was therefore used only in the event filter to check for correlation between the two phototube pulse heights, and not to measure the multiplicity jump.

K^0_s's that decay in the first 2 cm downstream of the target are very rare at our energies, but using our large data sample we have a very clean signal from K^0_s's in this region (Figure 8). In almost all these events the other strange particle in the event decays well downstream of the target, so we expect to observe a multiplicity jump of exactly two. We calibrated out the detector offsets from Figures 4 and 5 by using events with a K^0_s decaying downstream of both quartz plates to center the multiplicity jump around zero as is shown in Figure 9. Figure 10 shows the measured multiplicity jump for events with a K^0_s decaying between the two quartz plates. The distribution clearly centers around 2 MIPS with a resolution only slightly worse than in Figure 6. This is clear evidence that the multiplicity trigger can detect the presence of secondary decays.

5. CONCLUSION

We constructed and tested a multiplicity jump trigger in a working experiment and it performed as expected. There is excellent correlation between the number of tracks found by the quartz plates and the SMD tracking program, and it detects a clear multiplicity jump in events in which the offline analysis found a K_s^0 in the decay region. The resolution is close to what is expected from photostatistics, but there is some evidence that fragments from the tungsten target contribute to the resolution. The resolution obtained is good enough to make an excellent beauty trigger in an experiment with a thin high density target. Future improvements in the photodetectors or in the Cherenkov radiators may improve the resolution beyond what we have achieved, and could allow this device to be used as a charm trigger as well as a beauty trigger.

6. ACKNOWLEGEMENTS

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6. P. Weilhammer, "Experience with Si detectors in NA32" Proc. of the workshop on "New Solid State Devices for High Energy Physics", Berkeley, 28-30 October 1985, LBL-22778 and CERN EP/86-54.
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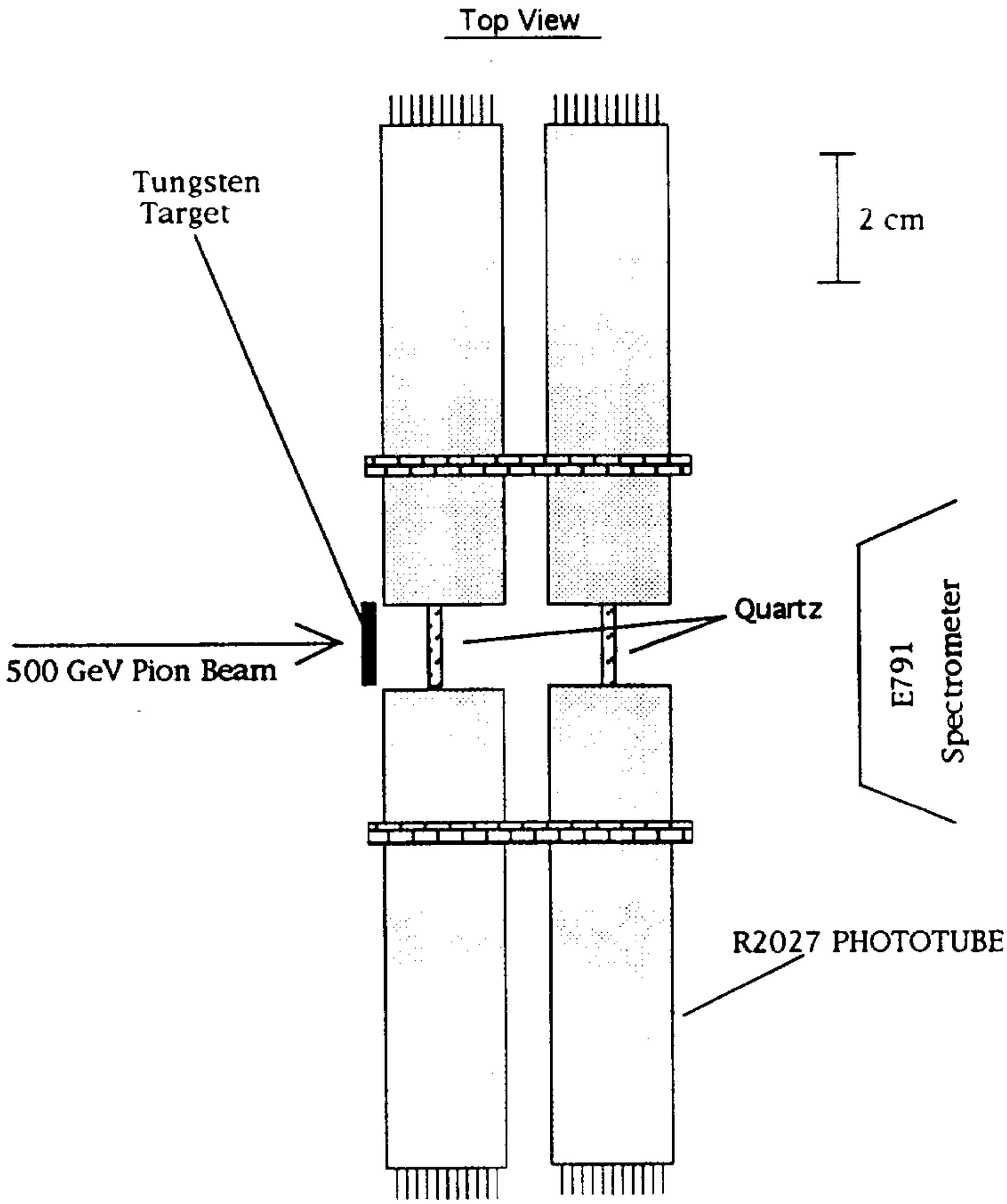

Figure 1. Top view of the test apparatus.

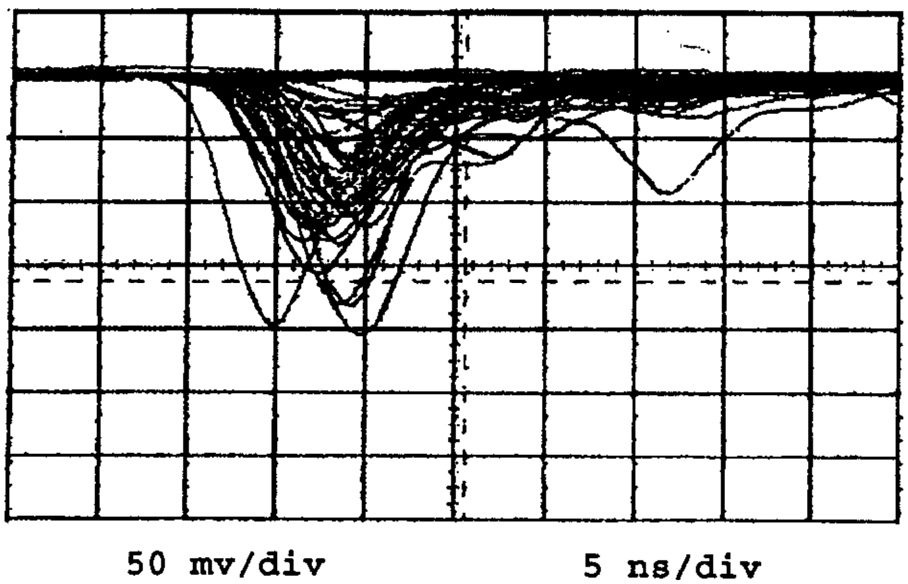

Figure 2. Single minimum ionizing signals from one of the phototubes after a factor of 10 amplification with a LeCroy 612A photomultiplier amplifier.

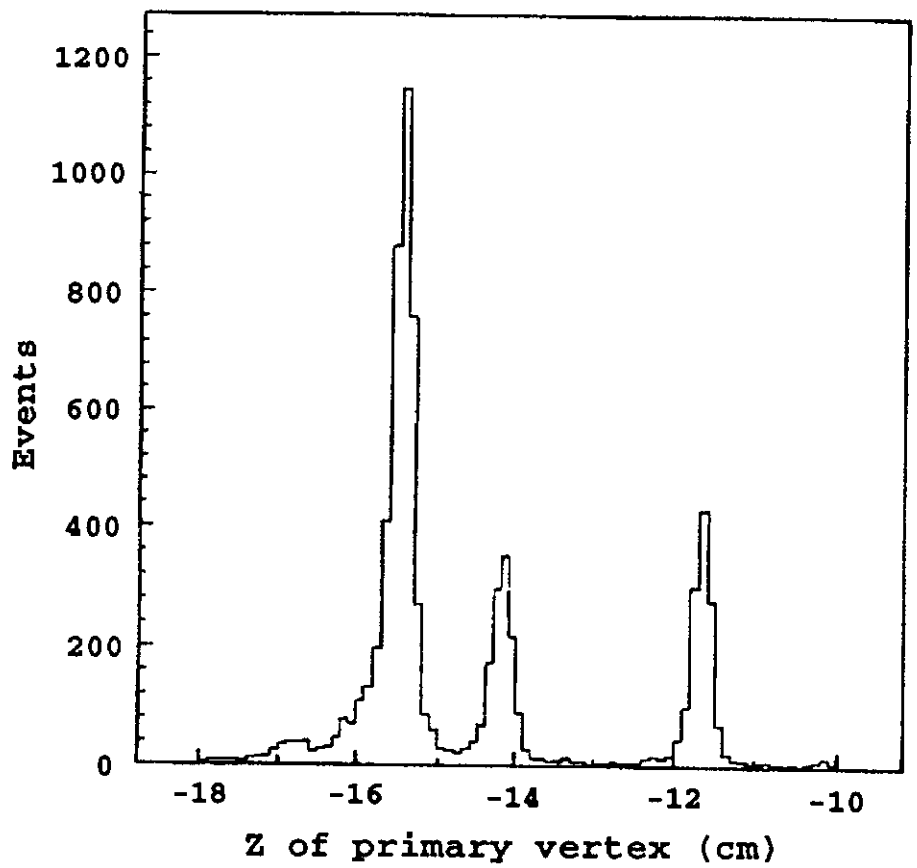

Figure 3. The reconstructed z position of the primary vertex for these events. The target, the two quartz plates, and the thin windows are clearly visible.

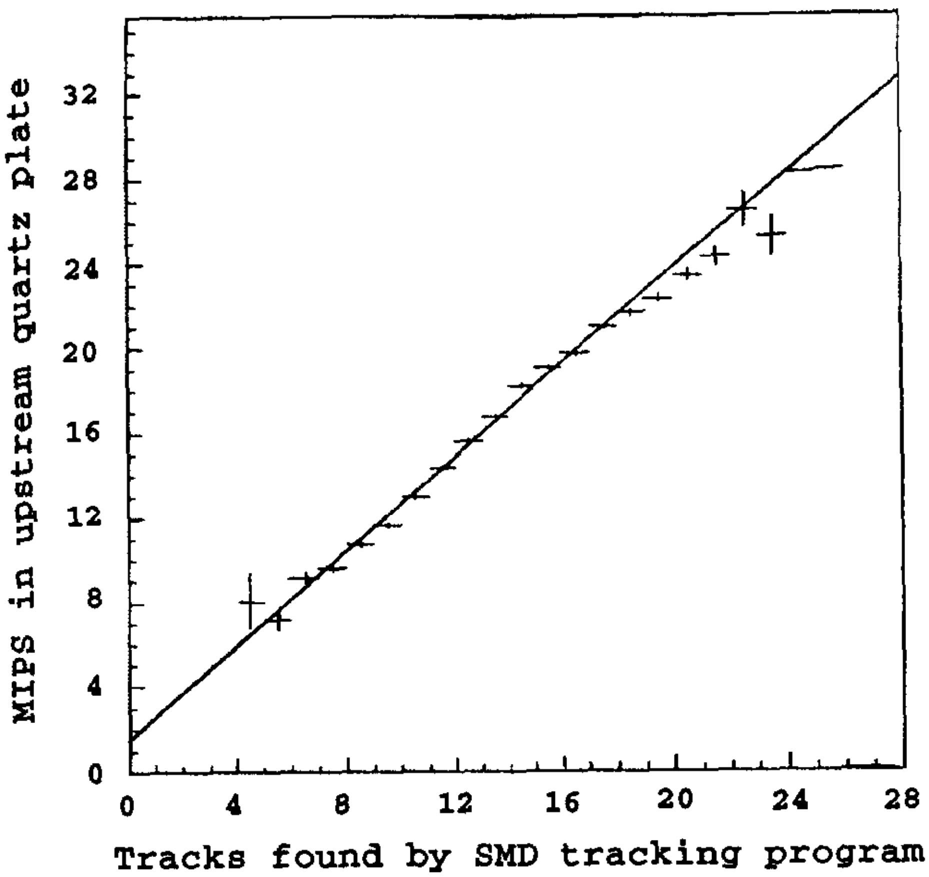

Figure 4. Correlation of normalized pulse height in upstream quartz plate with number of tracks reconstructed by offline analysis.

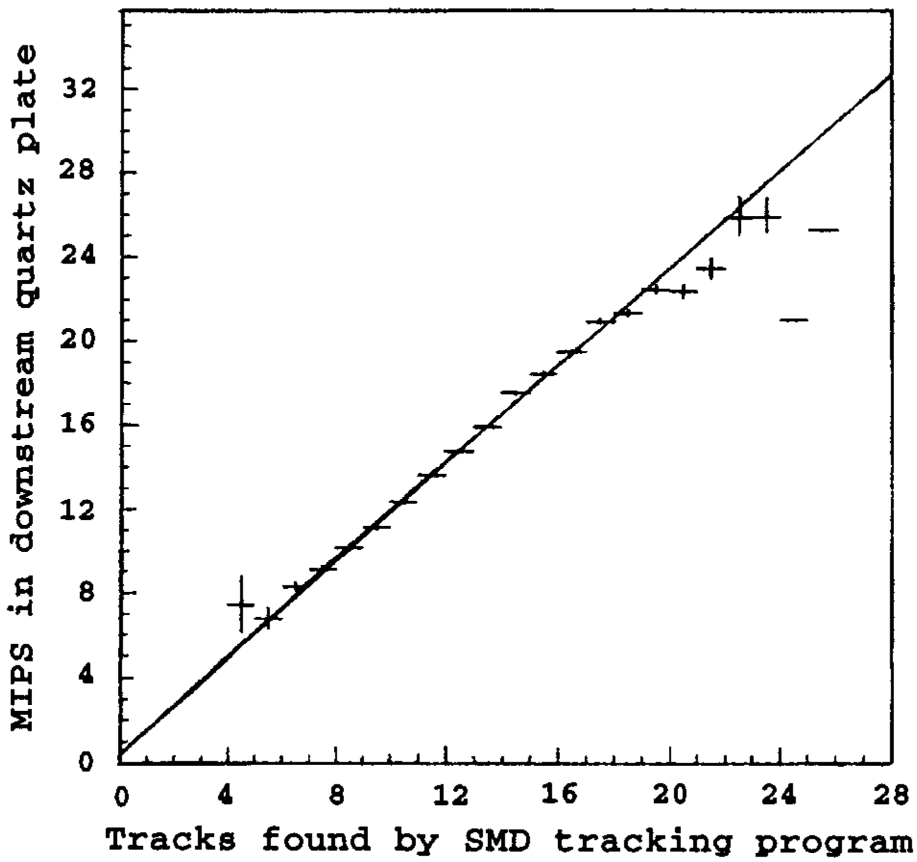

Figure 5. Correlation of normalized pulse height in downstream quartz plate with number of tracks reconstructed by offline analysis.

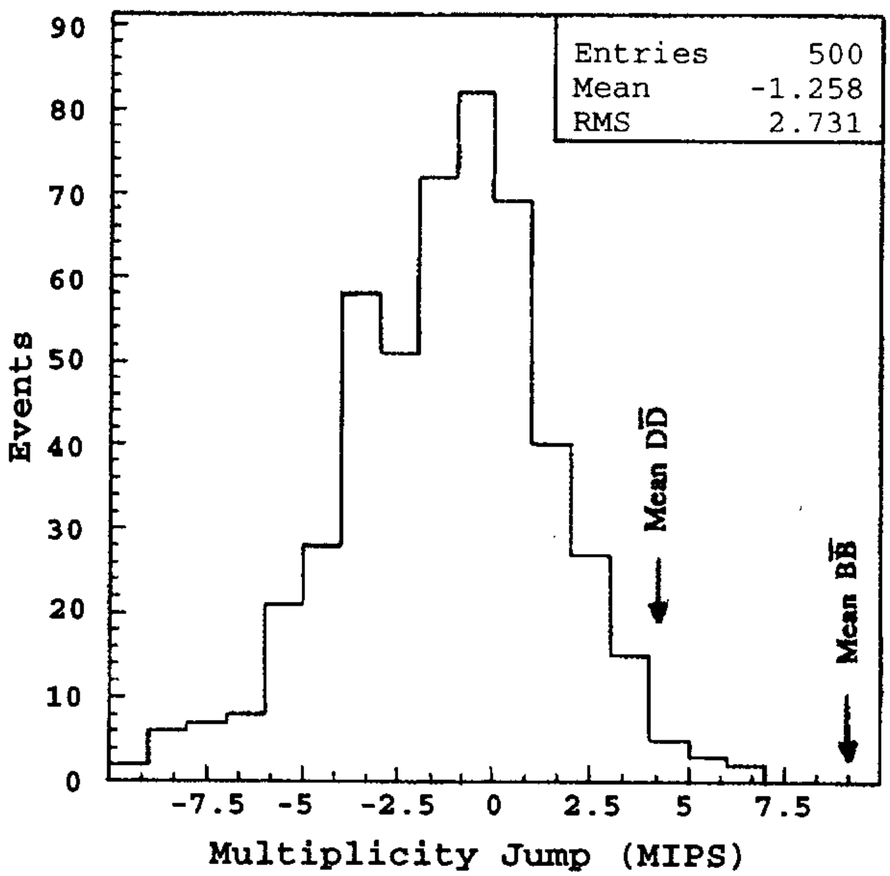

Figure 6. Measured number of particles appearing between the plates for interactions of multiplicity 6-20. Events with secondary vertices from heavy quark decays produce a positive signal. The arrows point to the approximate mean charged multiplicity for $D\overline{D}$ and $B\overline{B}$ events in which all the decays occur between the plates.

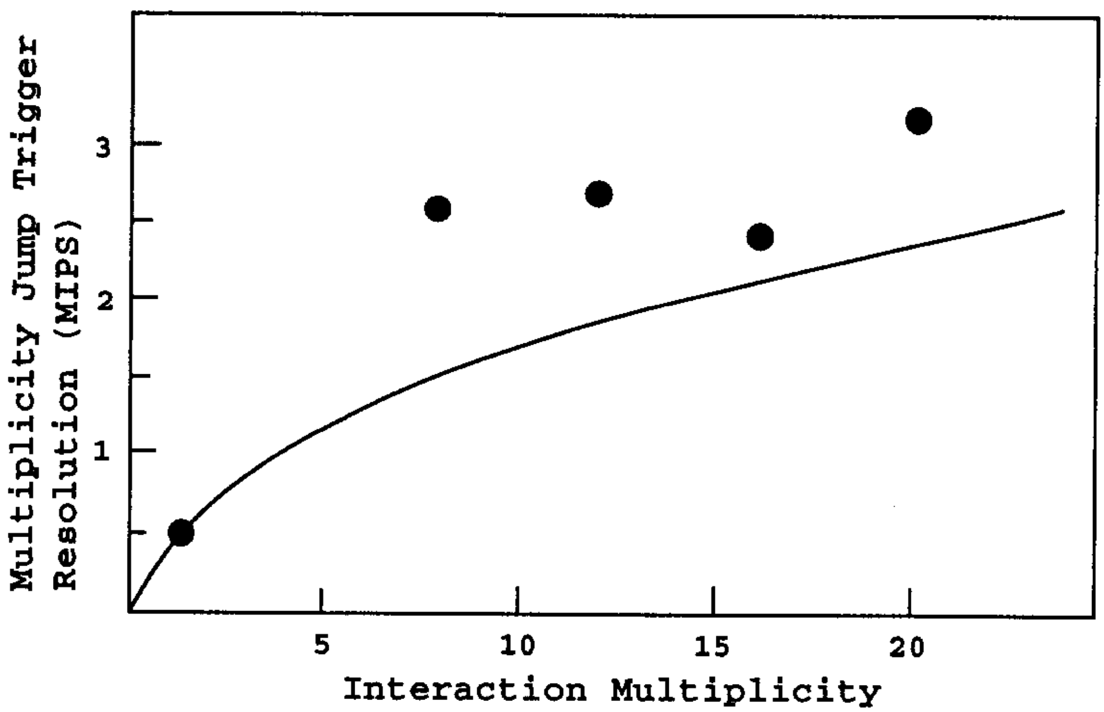

Figure 7. The measured detector resolution as a function of interaction multiplicity. If the resolution were dominated by photon counting statistics the resolution would increase as the square root of the interaction multiplicity as shown by the curve.

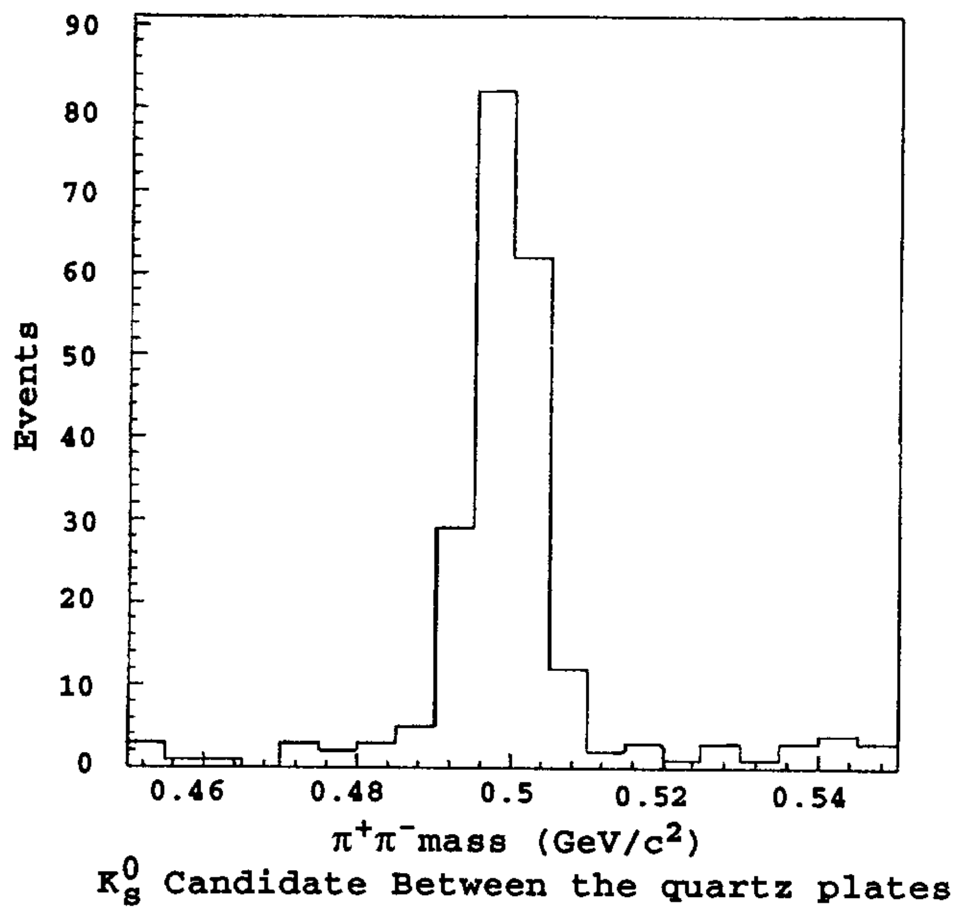

Figure 8. Measured $\pi^+\pi^-$ mass distribution for secondary vertices between the two quartz plates.

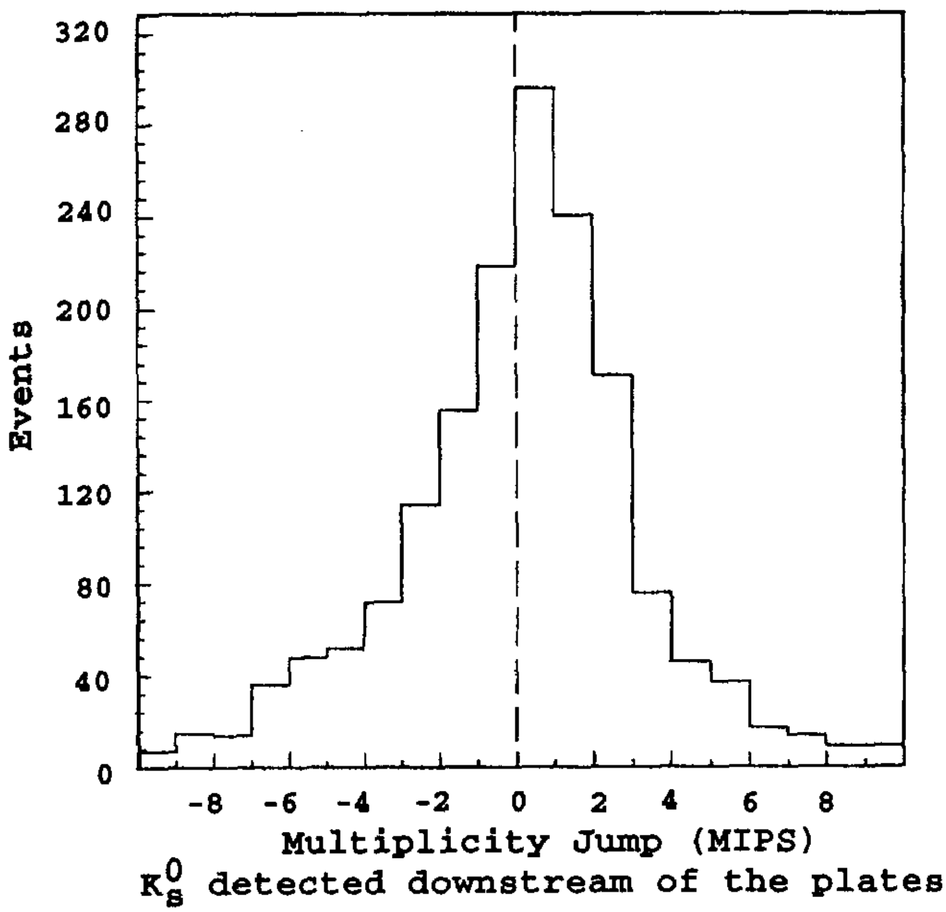

Figure 9. Measured multiplicity jump for events with K_s^0 decaying downstream of both quartz plates after calibration.

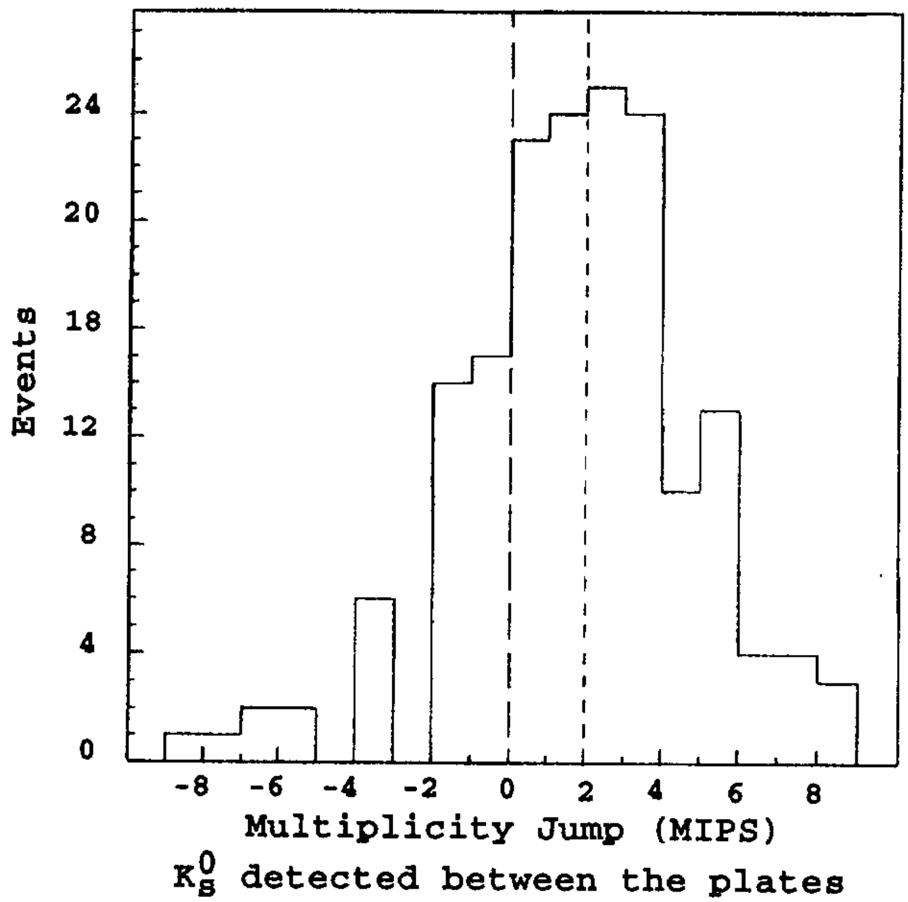

Figure 10. Measured multiplicity jump for events with a K_s^0 decaying between the two quartz plates.